



# Pineapple Cultivation in Hawaii\*

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## Overview of Commercial Production Practices

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Pineapple is a perennial plant that requires a functional root system to produce multiple fruitings. Economic production of 'Smooth Cayenne', the dominant pineapple cultivar grown commercially in Hawaii, has been based on a two- or three-fruit crop cycle requiring approximately 32 or 46 months, respectively, for completion. A field newly planted with crowns requires approximately 18 months after planting before the first fruiting,

referred to as the "plant crop," is harvested. Two subsequent fruitings, referred to as "ratoon crops," are produced from vegetative suckers (also called shoots) on the plant. Fruits are harvested year-round for fresh market and canning operations. Generally, production levels and fruit quality are highest during the summer.

During growth and flowering but before fruit development, fertilizers, herbicides, insecticides, nematicides, and fungicides may be applied to maintain crop growth and control weeds, pests, and diseases as needed to maintain a healthy crop, as follows:

- Fertilizers—preplant; postplant via drip irrigation, foliar broadcast sprays
- Herbicides and insecticides—preplant; postplant via broadcast or spot application
- Nematicides—preplant; postplant via drip irrigation, foliar application during plant development
- Fungicides—preplant via crown dips, postplant via foliar sprays

Common practice in the industry is to apply only the minimum amount of pesticide required to achieve control, to wait as long as possible between applications, and to minimize the number of applications. These practices reduce environmental and health risks while ensuring adequate control of pests and maximum economic benefit. Generally, pest-control chemicals are not applied during the 5–6-month fruit development period before harvest.

## Field operations and equipment

### Mulching

After field preparation, a machine lays a thin plastic mulch film marked with the plant spacing; beneath this mulch it also lays a plastic tube for drip irrigation, injects a fumigant for nematode control, and applies fertilizer.

\* This document combines two previous publications of the College of Tropical Agriculture and Human Resources.

The first section, "Overview of commercial production practices," is adapted from *Pineapple, the plant and its culture*, by Kenneth G. Rohrbach, published under the imprint of the Hawaii Agricultural Experiment Station, Hawaii Institute of Tropical Agriculture and Human Resources, University of Hawaii at Manoa (5 pp., no date [ca. 1990]). The brochure provided a snapshot of the pineapple crop cycle as then practiced by the major commercial plantation growers in Hawaii.

The second section, "Growing pineapple," was first published in 1988 under the title *Pineapple* as CTAHR Commodity Fact Sheet PIN-3(A). It was intended as a "how-to" guide providing information for someone wishing to cultivate a crop of pineapple.

**Boom spray**

Truck-mounted boom sprayers apply foliar fertilizers, pest-control chemicals, and growth regulators when necessary from roads equally spaced throughout the pineapple fields.

**Drip irrigation**

Water is applied through a system of pipes to a small plastic tube called a “drip tube.” The tube, with holes spaced so that each plant receives water, is located between the plant rows under the mulch film.

**Crop management sequence*****Crop preparation and mulching***

After a 3–12-month fallow period and field preparation, preplant soil fumigants and fertilizers are applied to the soil under the mulch film to protect the root system from pests and diseases, particularly nematodes, and ensure a uniform plant start.

***Planting***

Planting materials (crowns) are treated with fungicides and/or insecticides before planting. Marks on the mulch film serve as planting guides to ensure a specific plant population. After mulching and/or immediately after planting, pesticides are applied with the boom spray to control insects and weeds.

***Growth period (months 2–11)***

Additional plant nutrients and pesticides are applied over the planting by boom spray or through the drip irrigation system as needed to maximize yields. Plant nutrients are applied in increasing amounts as the plants be-

come larger. Flowering and fruit development are induced with forcing chemicals (growth regulators) when the plants are big enough to maximize yield and product recovery. Scheduled forcing of flowering synchronizes the subsequent harvest with anticipated market demand.

***Fruit development (months 11–18)***

After forcing, the plant enters the “redbud” stage and then flowers. Fruit development occurs during months 14–18. Very few nutrient applications are made during the flowering and fruit development periods. Pest control chemicals are rarely applied during this period, and only when absolutely necessary.

***Harvest (month 18)***

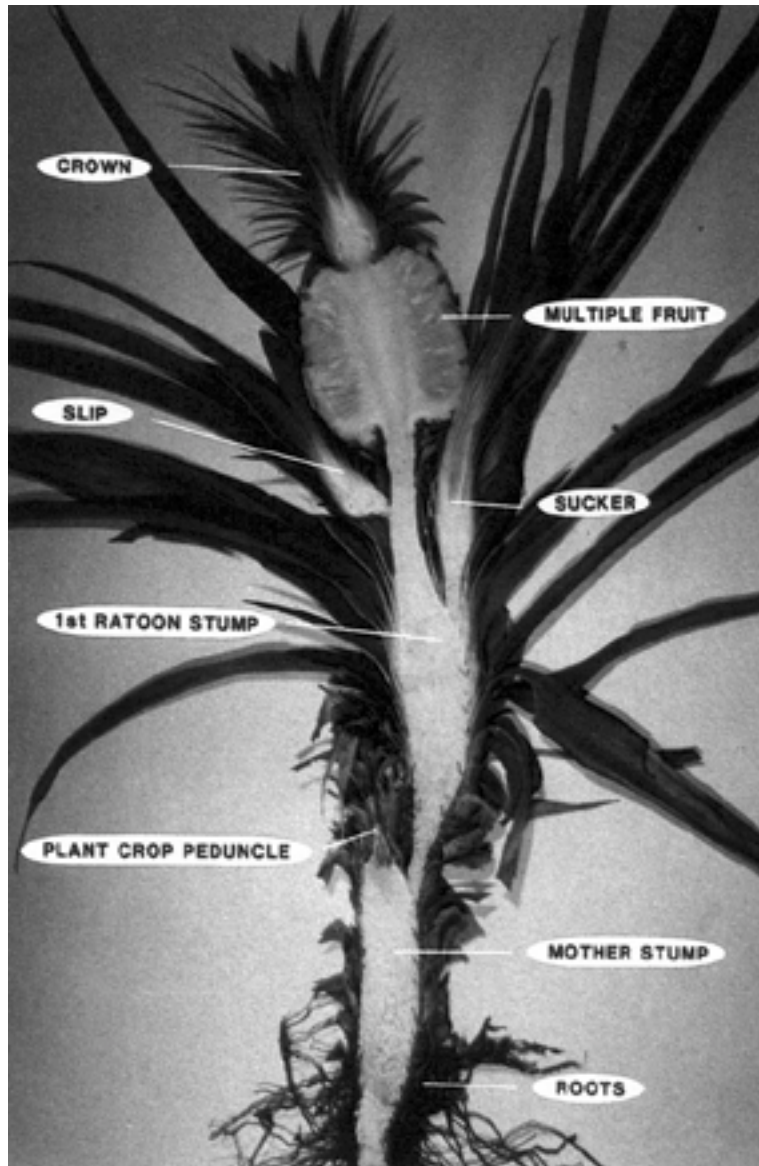
Pineapples are picked by hand and conveyed to a truck on a moving belt boom. On the truck, they are carefully stacked in bins for transport to the fresh fruit packing plant.

***Ratoon crops***

First ratoon sucker development begins when the plant crop is harvested. Plant nutrients are applied, and pest control chemicals are applied only if there is a pest outbreak. The ratoon crop is forced at about month 25. Very few nutrient applications are made during the flowering and fruit development periods; pest control chemicals are not scheduled, being applied only if there is a pest outbreak. Harvest is during month 32.

These practices are repeated if the crop is kept for a second ratoon, with forcing at about month 39 and harvest at month 46.

**The parts of a pineapple plant  
(cross-section of a first-ratoon plant)**



Reproduced from *Pineapple, the plant and its culture*, by Kenneth G. Rohrbach, Hawaii Agricultural Experiment Station, Hawaii Institute of Tropical Agriculture and Human Resources, University of Hawaii at Manoa, 5 pp., no date (ca. 1990); original photo courtesy of Dole Packaged Foods Co.

## Growing Pineapple

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**P**ineapple (*Ananas comosus* L. [Merr.]) is a perennial herb in the botanical family Bromeliaceae, native to the American tropics. It grows to 50–100 cm tall.<sup>1</sup> It has narrow, tapering, pointed leaves up to 100 cm long arranged in a spiral rosette, crowded on and tightly clasping a central stem. The leaf margins are usually but not always spiny. The inflorescence consists of 100–200 flowers arranged in a compact spiral cluster. The flowers are perfect, with a floral bract, three short fleshy sepals and petals, six stamens, and an inferior ovary with three locules. Commercial clones are selfsterile but cross easily with plants outside their varietal group. The fruit is a terminal cylindrical, compound structure at the apex of the stem and is formed by the fusion of the berrylike fruitlets that develop from the flowers. At its apex, the fruit bears a compressed, leafy shoot called a crown. The typically yellow fruit flesh is best eaten when sweet and moderately acid; it may contain from 10 to 18 percent sugar and from 0.5 to 1.6 percent titratable acidity.

### Varieties

Cultivated types of pineapple are called “clones,” because they are vegetatively propagated. There are many named clones, classed in four or five groups including ‘Cayenne’, ‘Spanish’, ‘Queen’, and ‘Pernambuco’, which may represent botanical varieties. Commercial production is mostly based on clones in the ‘Cayenne’ group, also known as ‘Smooth Cayenne’ because the leaf margins lack spines. In Hawaii, strain selections from field populations of ‘Smooth Cayenne’ are grown almost exclusively.

### Flowering

Flower initiation takes place at the terminal axis of the stem. This occurs naturally on short, cool days, usually in December in Hawaii. The inflorescence is not externally visible for 45–60 days, when it appears in the center (heart) of the plant. Stages of development after its appearance are called “half-inch open heart” and “one-inch open heart.” At these stages, the center is open approximately 1.25 and 2.5 cm, respectively, and the red inflorescence is clearly visible below the opening. Three to four weeks after the one-inch open heart stage, blue flower petals can be seen at the bottom of the cone-shaped inflorescence. Before all flowers have opened, the earliest petals will have begun to dry. After all petals have dried, the inflorescence is said to be at the “dry petal” stage. Its surface is dull, individual fruitlets (“eyes”) are pointed, and a crown has just begun to develop.

Although flowering occurs naturally only at certain times of year, artificial induction of flowering with chemicals, called “forcing,” may be done at any time of year if the plants are large enough (at least 1.5 kg fresh weight). This permits scheduling of planting and flowering so that harvests can be spread throughout the year. It is also used in “closing out” the crop to assure a complete and synchronous change at the time of natural flowering. Forcing is sometimes not completely effective during hot weather.

### Production

Three companies dominate pineapple production in Hawaii. Large areas are planted on the islands of Lanai, Maui, and Oahu. Most of the production previously was canned, but there is an increasing trend toward producing for the fresh fruit market. There is some smallholder production on the islands of Maui and Hawaii.

### Location

Pineapple is produced in Hawaii at elevations below 840 m (2800 feet) with mean annual temperatures ranging from 18.5° to 26°C (65°–79°F). Good fruit quality is attributed to growing sites having a combination of relatively cool night temperatures, a high percentage of sunny days, and day temperatures ranging from 21° to 29.5°C (70°–85°F), and not exceeding 32°C (90°F). Wind is seldom a problem. Drought is tolerated, but yields are reduced when adequate moisture is lacking.

<sup>1</sup>Use the following relationships to convert from metric to Imperial measure: 1 inch = 2.54 centimeters (cm); 1 foot = 30.5 cm; 1 gallon/acre = 9.4 liters/hectare (ha); 1 ounce = 28.4 grams (g); 1 pound = 0.454 kilogram (kg); 1 pound/acre = 1.12 kg/ha; 1 plant/acre = 2.47 plants/ha.

Evenly distributed rainfall of 60 cm per year is adequate for maximum growth.

### **Soil types**

Acid soils are especially suited to pineapple. When soil pH is between 4.5 and 5.5, soil-borne diseases are reduced. Soil pH greater than 7.0 should be avoided. Good soil drainage is a necessity. Where rainfall is high or soils are not well drained, soil management techniques to improve drainage must be used. Pineapple tolerates low soil fertility, but best production is obtained with high fertility. High levels of soluble soil aluminum and manganese are tolerated. High soil organic matter and potassium status are desirable.

### **Propagation**

Pineapple is propagated asexually from various plant parts. For production purposes, the parts used are crowns, slips, hapas, and suckers, with crowns and slips being most common. The number and proportion of slips, hapas, and suckers produced on the plant vary with clone and climate. Special techniques are used for rapid increase of strain selections.

#### ***Rapid increase methods***

Tissue culture using meristem from axillary buds is possible if callus culture is avoided. Plants regenerated from callus tend to be variable. Growth regulators known as morphactins applied after forcing can cause production of up to 25 slips per plant. Two traditional methods are stump (stem) and crown sectioning. Plants obtained by sectioning develop slowly, and extra care in field preparation and irrigation is needed to promote rapid growth.

***Stump sectioning.*** Stumps are harvested after the one-inch open heart flowering stage or after fruit harvest. Leaves are stripped off starting at the base, or they are cut off leaving the leaf bases attached to the stump. The stump is cut longitudinally into quarters or sixths, which are then cut into wedge-shaped sections weighing 15–20 g, each having at least one axillary bud. The sections are dipped in fungicide and planted bud upward 2.5 cm apart and 2 cm beneath the soil in a well-prepared, fumigated nursery bed. The bed may be lightly mulched with straw or compost. As many as 50 sections may be obtained per stump. A section will produce another stump in about two years.

***Crown sectioning.*** Crowns are cut vertically into

quarters or sixths, starting at the top and cutting toward the base. The vertical sections may be cut horizontally in half between the crown base and apex. After drying for one to two days, the sections are dipped in fungicide and sown 2.5 cm apart in nursery beds, with the leaves above ground. Plantlets from crown sections should reach the original crown size in less than one year. Under semisterile conditions, crowns have been micro-sectioned to produce up to 100 plants.

### ***Crowns***

Crowns are currently the preferred planting material in Hawaii. They are twisted from the fruit at the time of harvest. The wound is allowed to dry (“cure”) for one to two weeks or, more commonly in Hawaii, the crowns are dipped in fungicide and planted soon after harvest. The chance of rot is reduced by trimming the crown butt to remove fruit tissue high in sugars. Crowns grow more slowly and are less drought resistant than slips but may have the potential to develop better root systems. Crowns should be graded by weight to minimize variability in the field.

### ***Slips***

A slip is a rudimentary fruit with an exaggerated crown. Slips develop from buds in the axils of leaves borne on the peduncle (fruit stalk). Because they must grow outward, then upward from under the fruit, slips are curved at the base. On slip-producing clones, the number of slips can vary from none, as is common in hot, equatorial zones, to as many as 10 or more, as is observed in the undesirable mutation known as “collar of slips.” Some clones never produce slips.

Slips become visible on the peduncle when the fruit is about half developed. When intended for use as planting material, they are harvested two to five months after the plant crop harvest, that is, 10–13 months after slip growth starts. When not so used, they are removed from the plant to increase ratoon yield. Slips are broken from the peduncle, then cured or dipped in fungicide. Slips may be stored butt end up in a dry place for up to one year, but they should be planted within one month of harvest for best results.

### ***Hapas and suckers***

Hapas are intermediate in form between slips and suckers. They are produced in small numbers on plants grown

in Hawaii, but in equatorial regions more hapas are produced than slips. They are borne at the base of the peduncle and, like slips, they are easily broken from the plant. Hapas are straighter than slips and lack the slip's imperfect fruit structure at the base.

Suckers develop from axillary buds on the stem. Growth usually begins at floral differentiation. After fruit harvest, suckers are cut from the stem with a knife. Because suckers are large when collected, they may flower precociously after planting, increasing harvesting costs. For this reason, suckers are not used for production in Hawaii.

### Harvest

When flower initiation occurs in December in Hawaii, ripe fruit is harvested 6–8 months later. If flowering is initiated by chemical forcing at other times of the year, the period may be shorter or longer. Fruit is harvested by bending it over and twisting to remove it from the stalk.

'Smooth Cayenne' fruit is ripe when the individual eyes become flattened and glossy and when shell color turns yellow to yellow-orange. Color development starts at the base and moves toward the top. 'Smooth Cayenne' is harvested when about one-third yellow for canning and when green for fresh fruit. Harvesting before ripening increases postharvest storage life, although harvesting when ripe is preferable for best fresh fruit quality. Cultivars other than 'Smooth Cayenne' may be green, yellow, red, or purple when ready to eat.

### Crop cycle

Before the use of growth regulators to force floral initiation in Hawaii, plants could grow vegetatively for 10–16 months. Now, pineapple is planted all year round and forced 9–13 months after planting. Duration of the "plant" crop is usually 15–20 months from planting to harvest. In warmer, equatorial tropical climates, the crop may require only 11–14 months: 6–8 months for the vegetative phase and 5–6 months from forcing to harvest.

When smaller fruit is desired for the fresh fruit market, the crop may be forced earlier than when larger fruit is required for canning. The larger the plant at the time of forcing, the greater will be the size of its fruit. In general, 'Smooth Cayenne' pineapple produces a fruit equal in weight to the plant fresh weight at flowering.

After plant crop harvest, one or more suckers continue to grow to produce the ratoon crop. Ratoons aver-

age about one fruit per plant with the high plant populations currently used in Hawaii. Ratoon crops are forced five to seven months after the plant crop harvest. Fruit of ratoons is usually smaller, sweeter, less acidic, and more aromatic than fruit of plant crops. A second ratoon can be taken in a good field having adequate soil fertility and low nematode populations.

### Cultural practices

Pineapple is one of the most extensively researched tropical fruit crops. Many aspects of production have been mechanized, and commercial cultural practices are highly refined.

#### *Soil preparation*

Soil should be well tilled. Addition of animal manures improves tilth, increases soil potassium, and may improve micronutrient availability. If the soil is imperfectly drained, beds at least 20 cm (8 inches) high should be formed. If nematodes are present in the soil, it should be sterilized, fumigated, or treated with a nematicide.

#### *Plant population*

Field plantings of pineapple are usually in double-row beds. A population of approximately 58,700 plants/ha will result from beds 122 cm from center to center, rows 55–60 cm apart within beds, and plants 28 cm apart within rows. Plantings for fresh fruit rather than canning fruit may reach 75,000 plants/ha, because smaller fruit is desirable. Within normal field population ranges, fruit size decreases about 45 g for each population increase of 2470 plants/ha.

#### *Mulching*

Black polyethylene approximately 90 cm wide is used as mulch in most commercial plantings in Hawaii. As the mulch is rolled out on the planting bed, its edges are covered with soil. Planting holes are punched through the plastic with a trowel. When nematicides are injected into the soil, plastic mulch makes them more effective by slowing their dissipation. The mulch increases soil temperature in the root zone, helps to conserve soil moisture, promotes rooting by concentrating moisture in the root zone, and controls weeds. Mulches are not used in equatorial climates with high temperatures and rainfall.

### **Irrigation**

Irrigation by the drip system to supplement rainfall is becoming standard practice in Hawaii. The tubing is laid in the center of each bed beneath the plastic mulch. There should be one tubing orifice for every two plants. When rainfall is lacking, the irrigation system should provide 47,000–94,000 liters of water per hectare per week to the plants. Crowns usually are “set” after planting by one overhead irrigation during dry weather.

Drip irrigation may be helpful to alleviate effects of root damage due to nematode infestation. Pineapple plants irrigated by drip lines are less susceptible to moisture stress because irrigation water is delivered directly to the root zone.

### **Weed control**

Weeds are controlled by black plastic mulch. To control weeds in bare soil areas between the mulch beds, registered preemergence herbicides cleared for pineapple may be used according to the instructions on the label. Some herbicide labels permit application of the herbicide as overtop sprays immediately after planting and at later stages during the crop cycle.

### **Forcing**

The growth regulator most commonly used for forcing is ethephon, an ethylene-releasing compound that is widely used for field applications. Ethylene and acetylene are also used for forcing. In commercial agricultural plantings, plants are forced with a solution containing ethephon mixed with urea.

Forcing with growth regulators is most effective during cooler seasons; hot weather is inconducive to good floral induction. During hot seasons (night temperatures greater than 25°C), withholding nitrogen (N) fertilizer for 4–6 weeks before forcing can improve induction by increasing plant carbohydrate relative to N.

### **Fertilizer**

Pineapple has high requirements for fertilizer N, potassium (K), and iron (Fe), and relatively low requirements for fertilizer phosphorus (P) and calcium (Ca). Less fertilizer is required during the first five months after planting; requirements increase sharply afterward and peak at two to four months before floral initiation. P and Ca are usually banded in the plant line during bed preparation. K is usually applied to the soil before planting and

later may be sidedressed. Other nutrients-sometimes including K are applied as foliar sprays or through the drip irrigation system, or by both methods, during the plant growth cycle.

**Preplant fertilizer.** The need for fertilizer applications to the soil is best determined by soil tests. In Hawaii, Ca need not be applied if soil pH is greater than 4.6, because of the low plant Ca requirement. If soils are low in P, approximately 75 kg/ha P should be broadcast or banded beneath the plant rows. Applications of animal manures may reduce the need for supplemental applications of Fe and other micronutrients.

**Postplant fertilizer.** Postplant applications of fertilizers to the plant crop may provide 450 kg/ha N (400–500 kg/ha is common), 400 kg/ha K, 25 kg/ha magnesium (Mg), and 2 kg/ha zinc (Zn). Frequent foliar applications of Fe are usually necessary in Hawaii because pineapple is not able to extract soil iron efficiently from low-pH soils. If Fe is moderately unavailable, 5–10 kg/ha iron sulfate ( $\text{FeSO}_4$ ) may suffice; where problems are more severe, as in Hawaii's pineapple soils, 6–24 kg/ha may be required.

**Foliar fertilizer.** The volume of fertilizer solution applied foliarly to pineapple varies with plant population, growth stage, and amount of fertilizer being applied. Concentrations of fertilizer applied in sprays must be carefully calculated to avoid solutions that burn the plants.

Low-volume sprays of 250–500 liters/ha are directed to the green portion of the leaves, allowing little or no rundown into leaf axils. Nutrient uptake is through green leaf tissue. Salt concentration may be as high as 20 percent by weight

Medium-volume sprays of 500–2500 liters/ha are directed to the green portion of the leaves, with rundown into leaf axils but with little or no runoff into the soil. Uptake is through green tissue, basal white tissue at leaf bases, and axillary roots near the base of the stem. Maximum salt concentration is 5 percent.

High-volume sprays greater than 2500 liters/ha are similar to medium-volume sprays except there is runoff of fertilizer solution into the soil at the base of the plant.

Urea is not phytotoxic at concentrations as high as 20 percent when applied to green leaf tissue only. The urea should contain less than 1 percent biuret. Fertilizer solution concentrations should not exceed 1 percent iron sulfate or 0.1 percent zinc sulfate.

**Fertilizer regimes.** Table 1 shows an example of a fertilizer regime for a plant crop cycle. Fertilizer is ap-

plied foliarly once a month, except for the preplant application (month 0), when Level I is incorporated into the soil. In addition to the amounts given in Table 1, about 50 kg/ha of nitrogen as urea is applied at forcing when ethephon is used. During the period between forcing and half-inch open heart, additional N may be applied if needed. Then applications should end, because fertilizer sprays will injure the inflorescence and reduce fruit yields.

Many fertilizer regimes are possible. For example, a constant fertilizer level (such as Level 2 in Table 1) could be applied with increasing frequency: monthly in months 1–3, every three weeks in months 4–6, and every two weeks afterward. Another alternative is to sidedress potassium sulfate every three months and apply foliar sprays of urea and iron sulfate as needed.

**Crop color.** Crop color can indicate its nutrient status. Pale yellow-green is acceptable during the first five months from planting in regions with a 12–13-month vegetative growth period. From month 5 to month 8, apply sufficient N to shift leaf color toward a darker yellow-green. After month 8, apply enough N to produce dark green plants. All yellow should be eliminated by the time of floral differentiation, or by the time N applications are suspended before forcing.

## Diseases

Heart and root rot (*Phytophthora cinnamomi*)

Heart rot (*P. parasitica*)

Root rot (*Pythium* spp.)

Black rot (*Ceratocystis paradoxa*)

Butt rot (*Thielaviopsis paradoxa*)

Fruitlet core rot (*Penicillium funiculosum*, *Fusarium mondifforme* var. *subglutinans*)

Pink disease of fruit (*Acetomonas* spp.)

Pineapple wilt (probable virus)

Yellow spot virus (tomato spotted wilt virus)

Bacterial diseases (*Erwinia carotovora*, *E. chrysanthemi*)

Nematodes (*Meloidogyne* spp., *Rotylenchulus reniformis*)

## Insect pests

Scales (*Diaspis bronwliae*, *Melanaspis bronwliae*)

Thrips, vectors of yellow spot virus (*Thrips tabaci*, *Frankliniella occidentalis*)

Mites (*Steneotarsonemus ananas*, *Dolichotetranychus floridanus*)

**Table 1. Example of a pineapple fertilizer regime for 58,710 plants/ha using a spray volume of 2500 liters/ha.<sup>a</sup>**

Level:	1	2	3	4	
Month:	0–3	4–8	9–10	11–12	
Applications:	4	5	2	2	
Fertilizer:					
Type	Amt. per application (kg/ha)				kg/ha/yr
Urea	48	72	98	120	988
Potassium sulfate	44	66	89	111	906
Iron sulfate <sup>b</sup>	7	10	14	17	140
Zinc sulfate <sup>b</sup>	2	3	4	5	41
Magnesium sulfate <sup>b</sup>	19	27	39	48	385

<sup>a</sup>It is assumed that phosphorus and calcium are incorporated before planting at levels based on soil test recommendations.

<sup>b</sup>Amounts given are for Hawaii's pineapple soils, where these nutrients may be in severely limited supply.

Mealybugs (*Dysmicoccus brevipes*, *D. neobrevipes*)

Ants, associated with mealybugs (*Pheidole megacephala*, *Iridomyrmex humilis*, *Solenopsis geminata*)

Symphylids (*Scutigerella sakimurai*, *Hanseniella unguiculata*)

## Selected references

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